



# Micro Inertial Reference System ( $\mu$ IRS)



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Dr. Tony K. Tang 4-20-98





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**I. Motivation**

**II. Background**

**III. JPL MEMS Approach**

**IV. Performance**

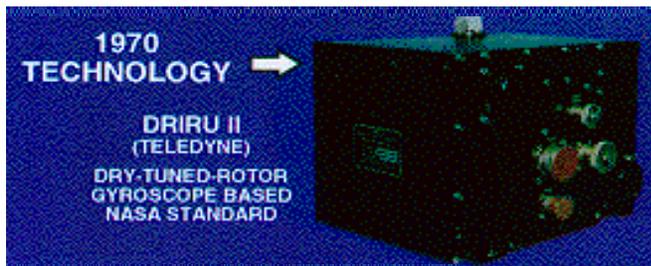
**V. Future Goals and Plan**



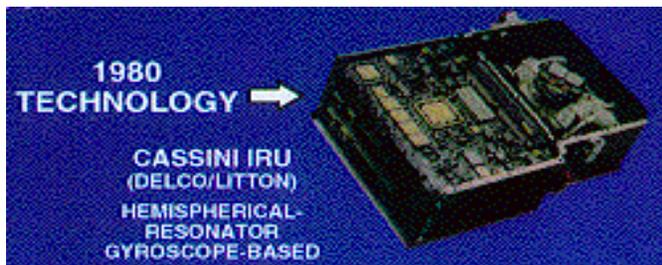
## I. Motivation

### Present Gyroscope and Inertial Measurement Unit Technologies

- Expensive
- Bulky (volume, mass)
- High power
- Limited lifetime

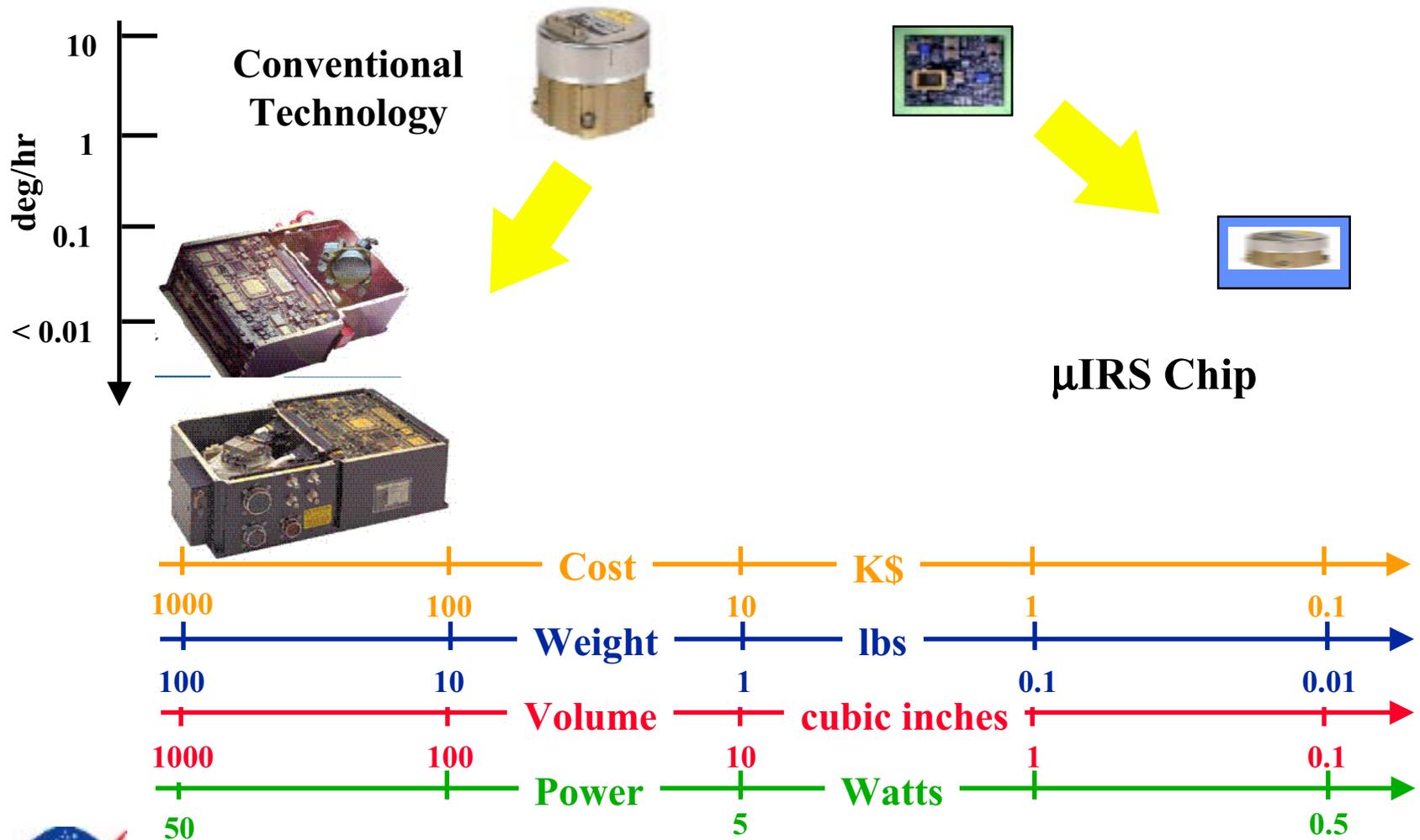


**MASS:** 17 kg (6 AXES)  
**SIZE:** ~ 28 x 30 x 33 cm  
**POWER:** ~ 22 Watts, Nominal  
**RATE** 2 deg/sec (max); (Higher input rates allowable)  
**CAPTURE:**  
**DRIFT:** 0.003 deg/hr



**MASS:** 5 kg (4 AXES)  
**SIZE:** ~ 28 x 20 x 10 cm  
**POWER:** ~ 18 Watts  
**RATE** 10 deg/sec(max); (Two ranges)  
**CAPTURE:**  
**DRIFT:** 0.01 deg/hr

## II. Background





# Micro Inertial Reference System ( $\mu$ IRS)



## Objective:

Develop a high performance, low cost, low power, reliable micro inertial reference system chip and technologies for space applications.

## Applications:

- Miniature guidance/attitude control and navigation system.
- Motion sensing/control/stabilization/compensation system.
- Station keeping, instruments and antenna pointing.
- Commercial safety system, terrestrial navigation, autonomous vehicle control and guidance, pointing devices.

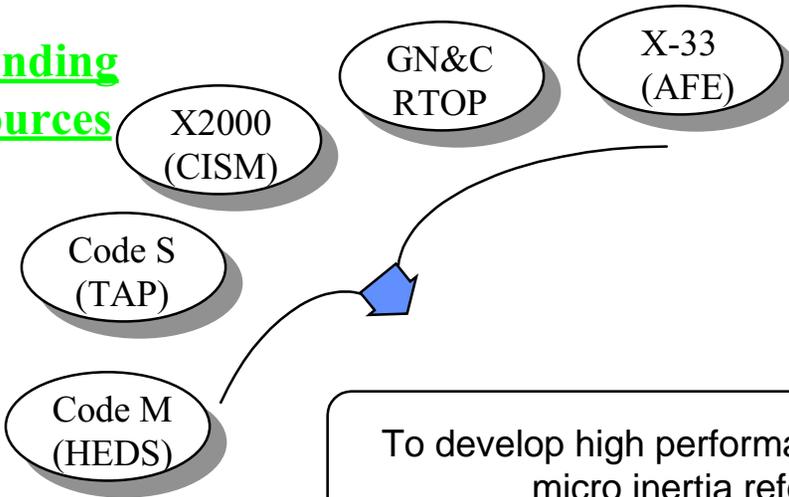




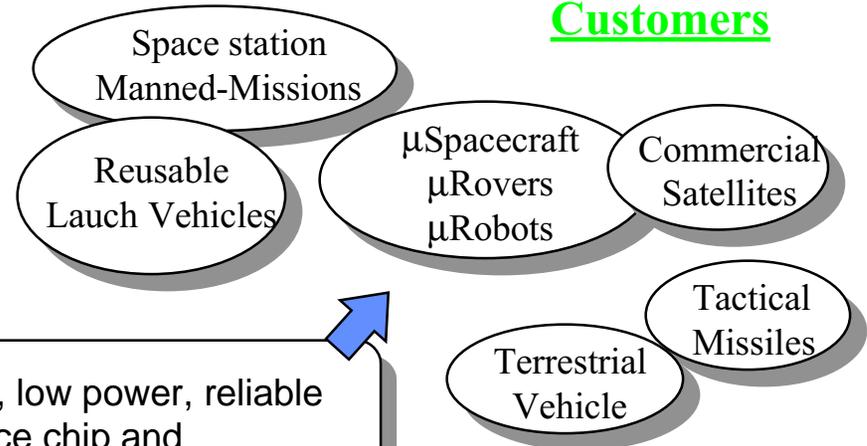
# Micro Inertial Reference System ( $\mu$ IRS)



## Funding Sources



## Customers



To develop high performance, low power, reliable micro inertia reference chip and technologies for space application.

## Academic Collaborators

## Industrial Collaborators

### **California Institute of Technology**

(Professor Bill Goddard)

Silicon & Diamond surface tribology & modeling

### **University of California, Los Angeles**

(Prof. Robert M'Closky, Steve Gibson, William Kaiser)

Digital control & modelling & circuit design for JPL MEMS microgyros.

### **Stanford University**

(Professor Thomas Kenny)

MEMS microgyro exploratory experiments.

### **Hughes Space and Communication**

Microgyro circuit development, modelling, Micro Inertial Reference Unit system development.

### **Raytheon**

Silicon & Diamond surface tribology experiment.

### **Welch Engineering, Inc.**

Micro Inertial Reference Unit system development.

### **Irvine Sensor, Inc.**

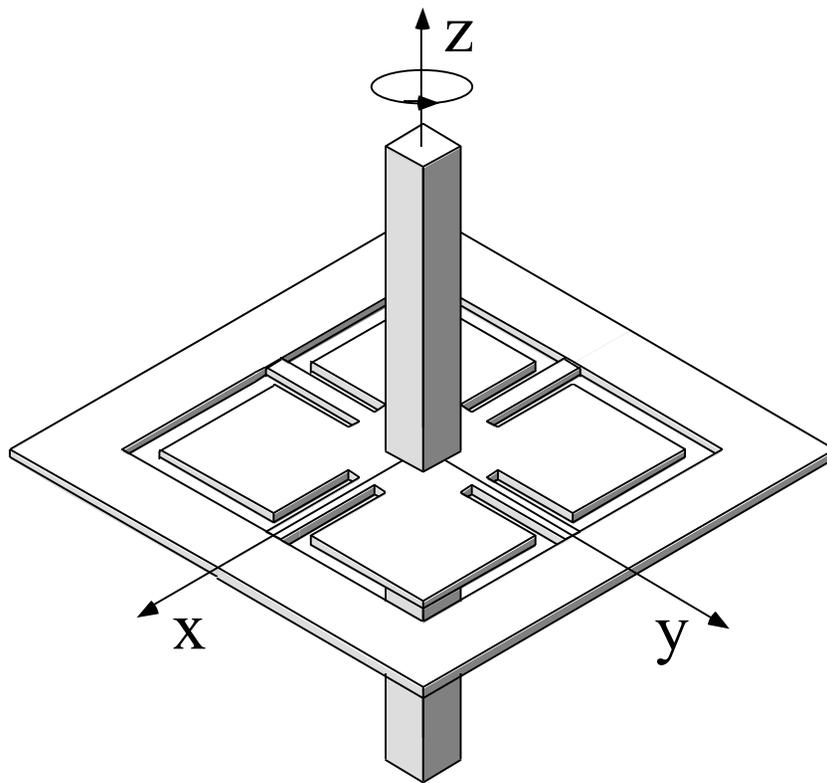
Microgyros testing.



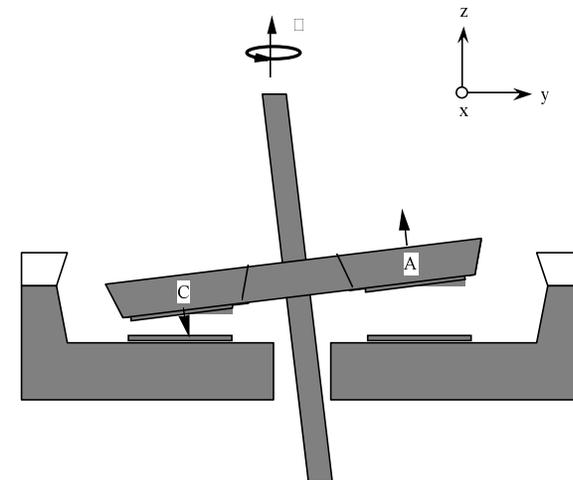
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## III. JPL MEMS Approach



The Clover-leaf microgyroscope design is based on sensing the oscillatory movements of adjacent paddles in and out of the z-plane due to rotation about the z-axis.





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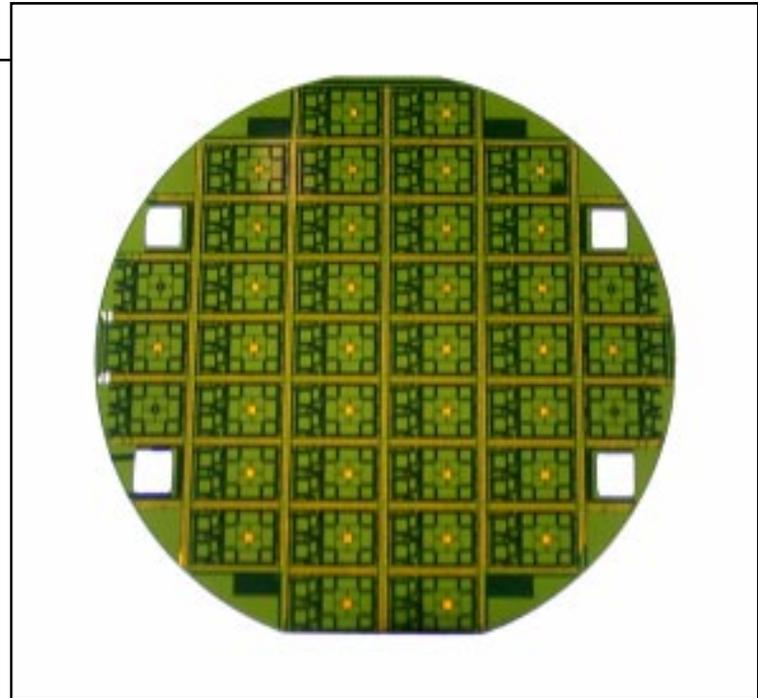
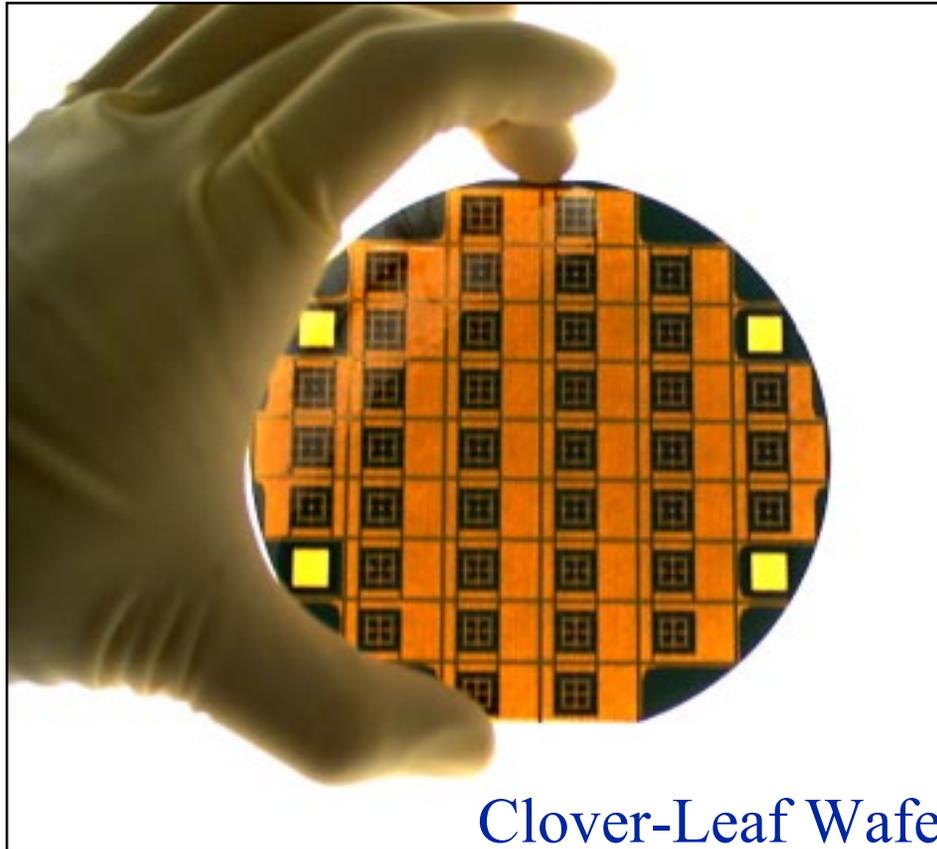


## Advantages:

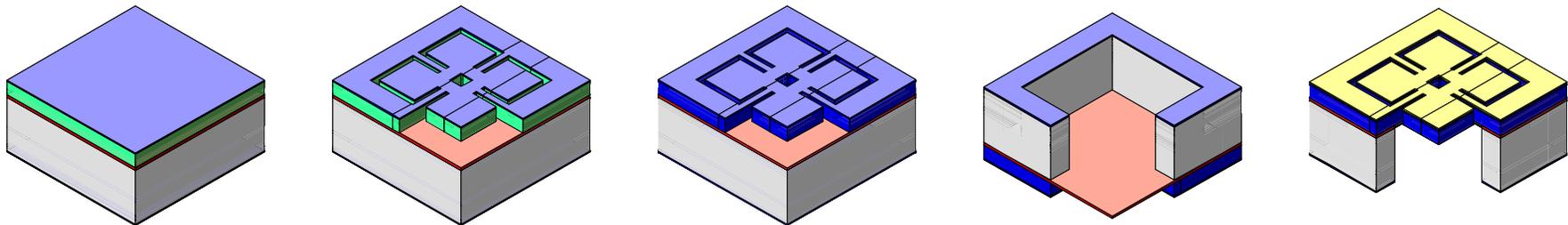
- Symmetric structural design:  
*Degenerate mode operation*
- High Q resonator:  
*High performance, Stability*
- Large detection/drive area:  
*Large signal, Low power*
- Simple & precise bulk- $\mu$ machining:  
*Fast turnaround, Low cost*
- Simple control electronics:  
*Reduced noise, cost & power*



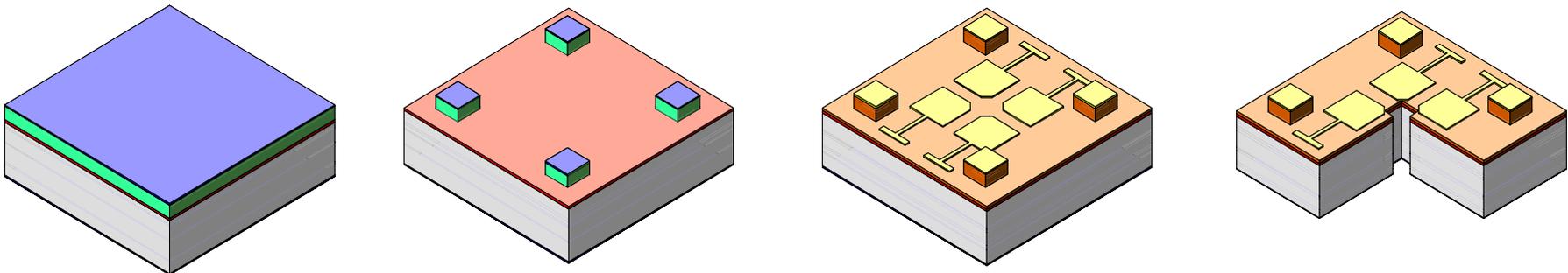
Full 4 inches wafer processing

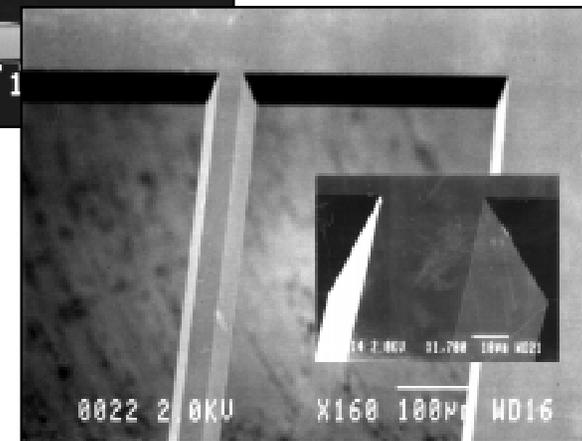
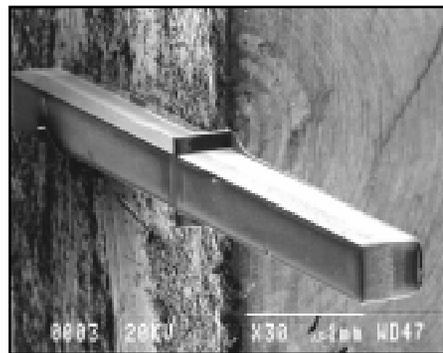
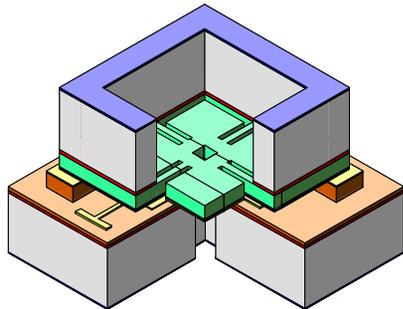
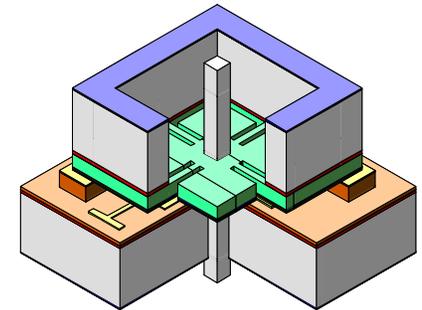
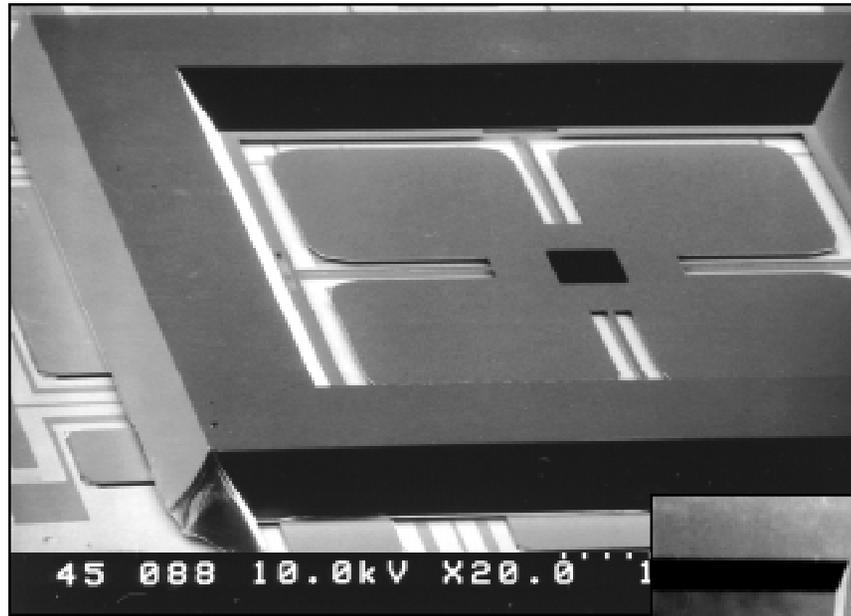
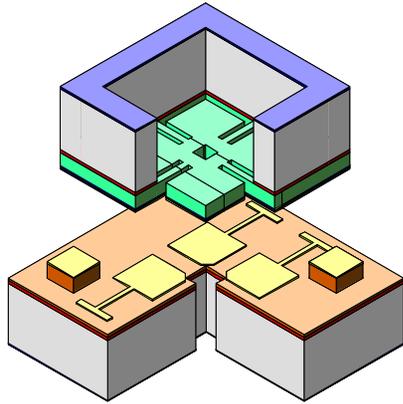


## Clover-leaf structure Fabrication:

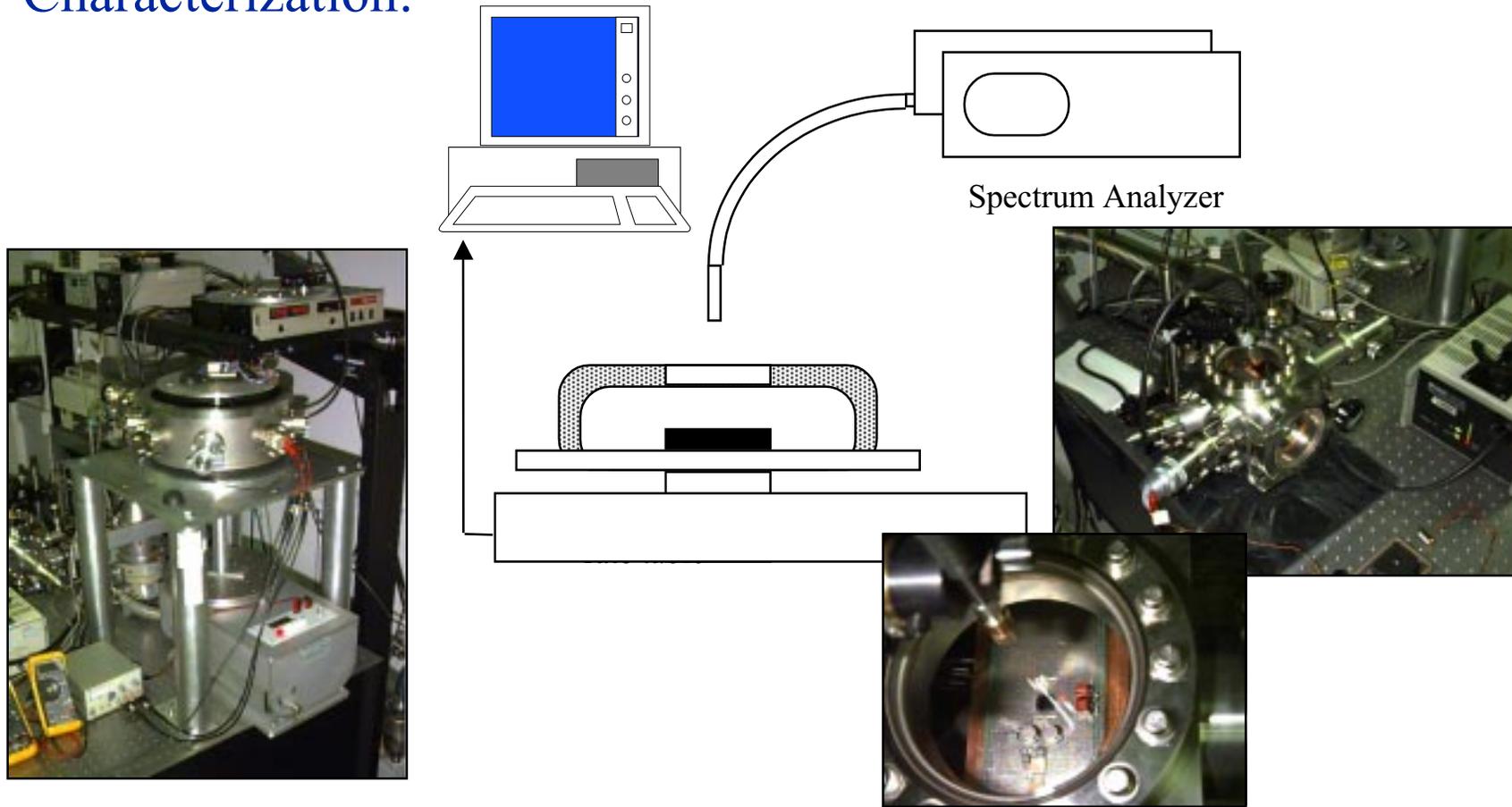


## Baseplate Fabrication:



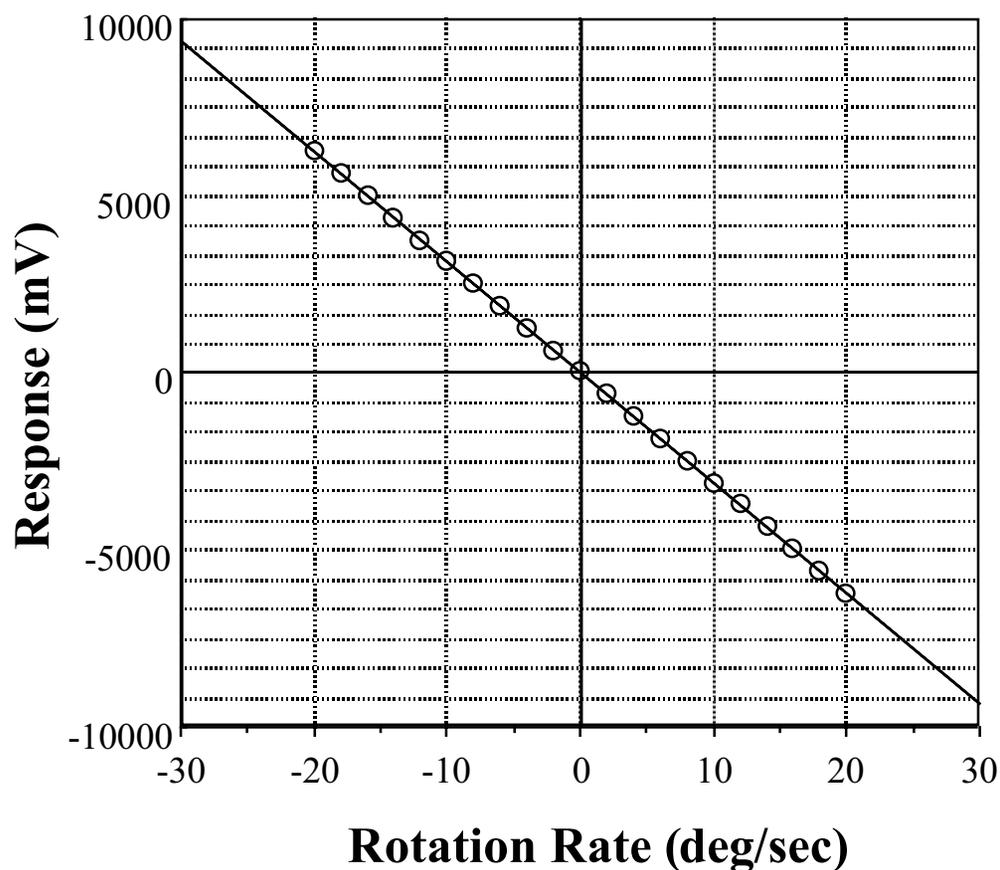


## Characterization:

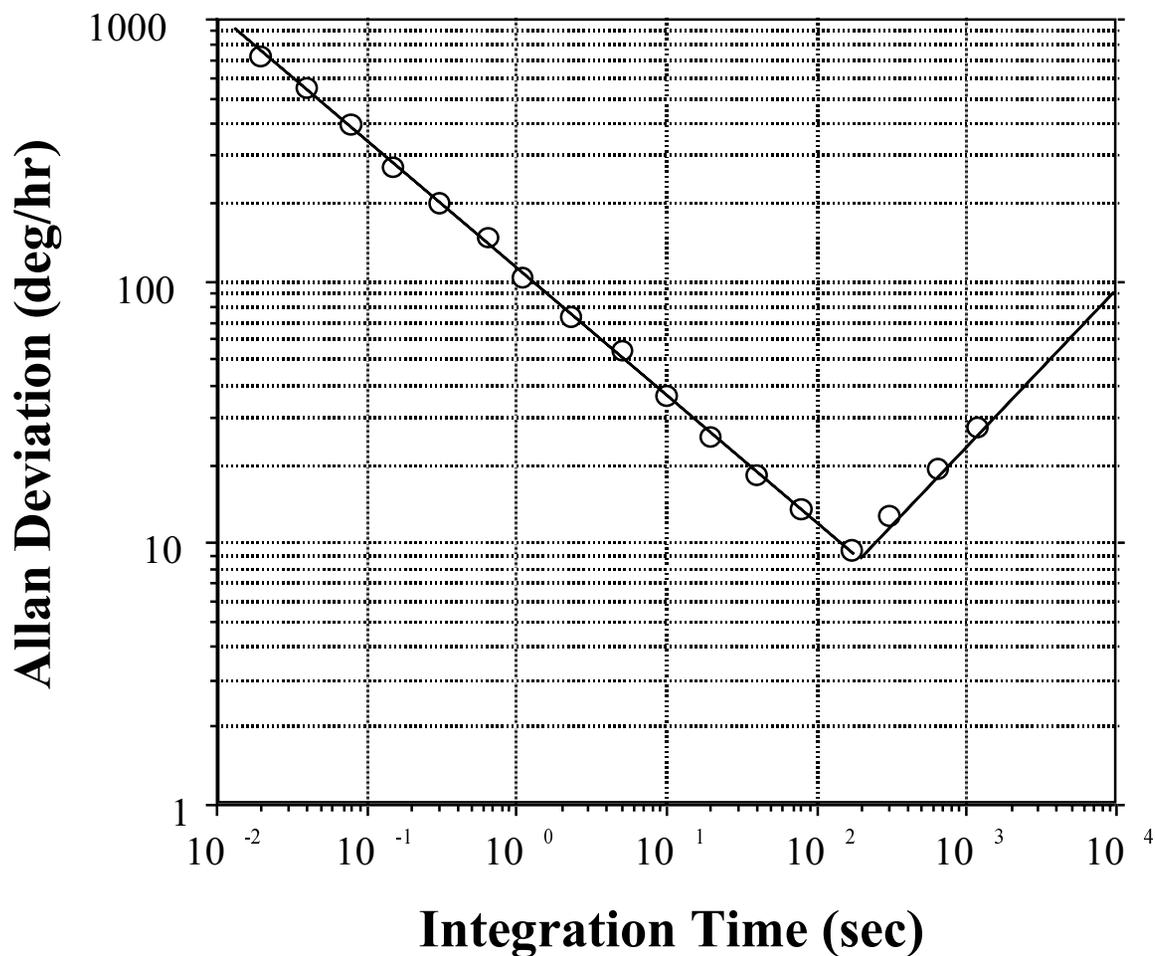


## IV. Performance

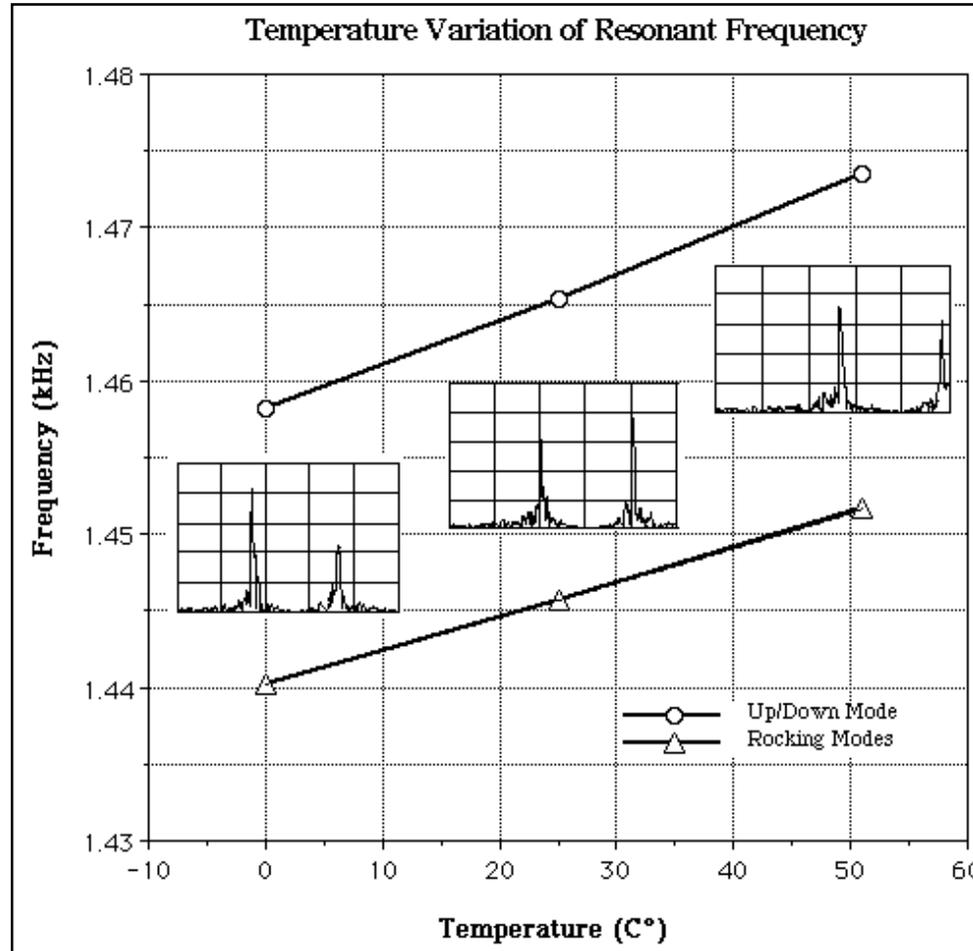
### Rotation Response



## Rate Green Chart

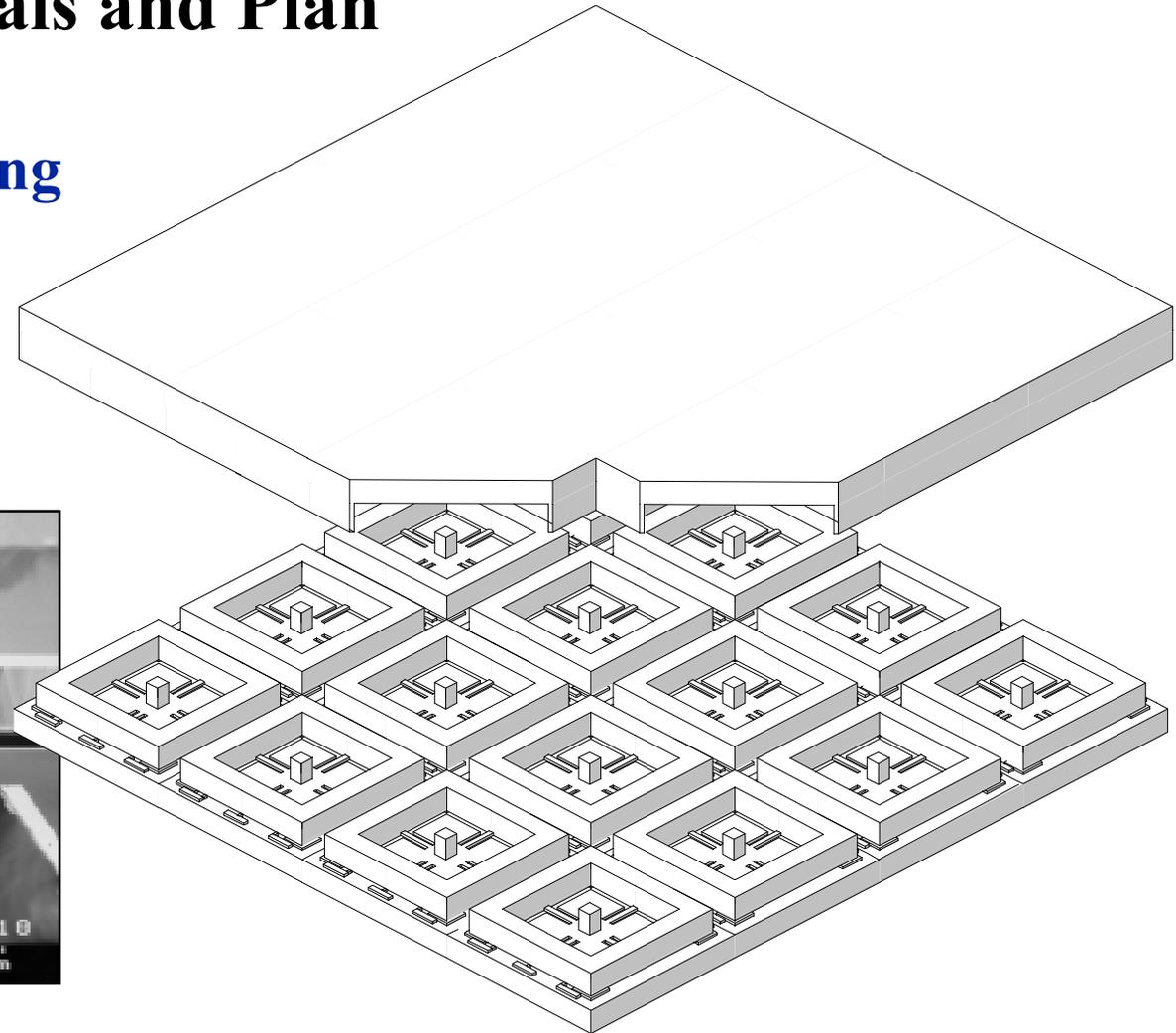
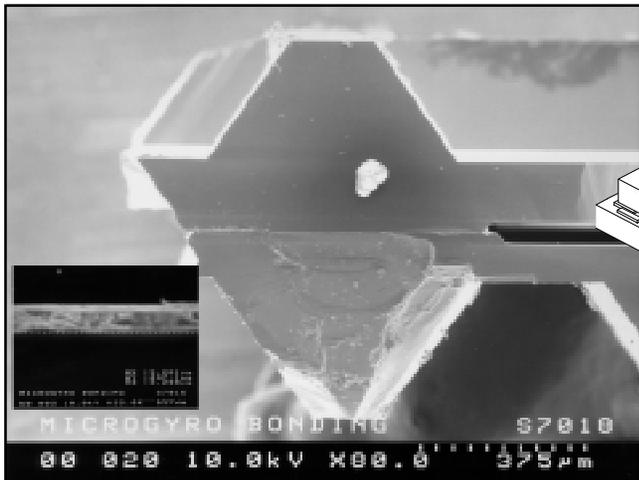


## Temperature Dependence

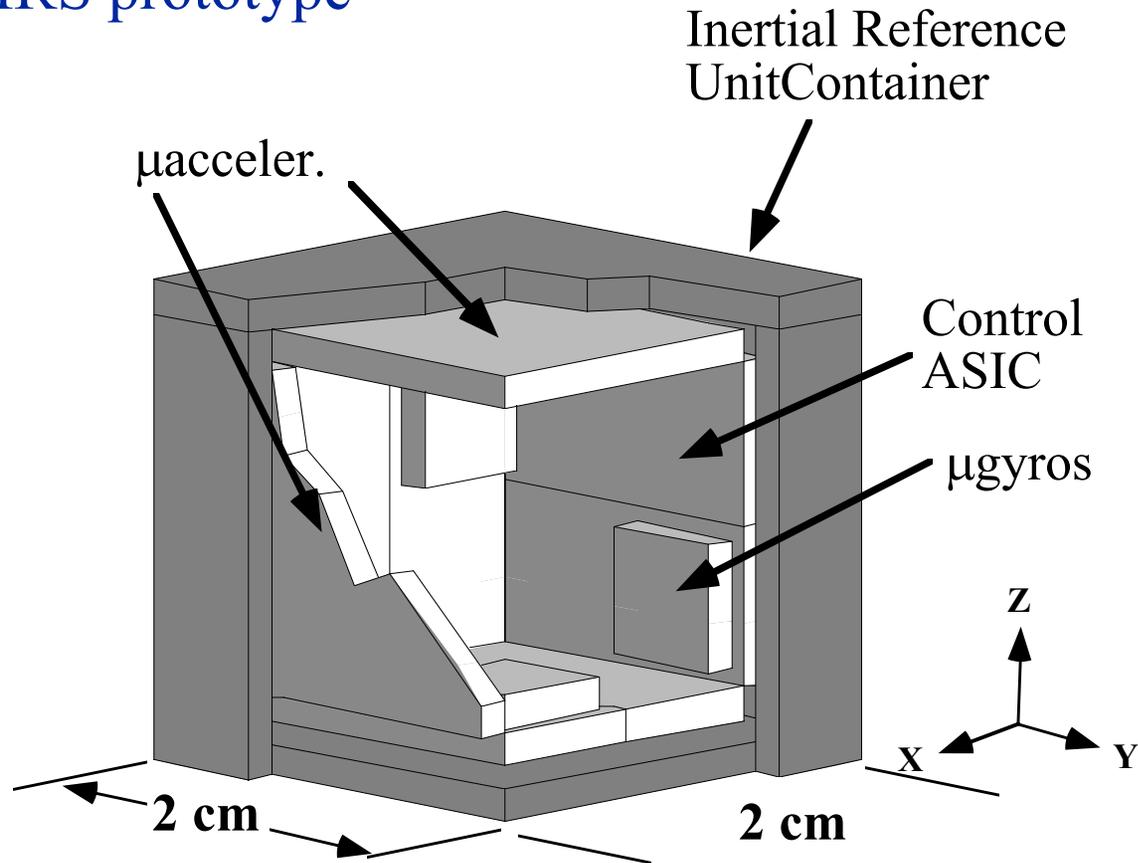


## V. Future Goals and Plan

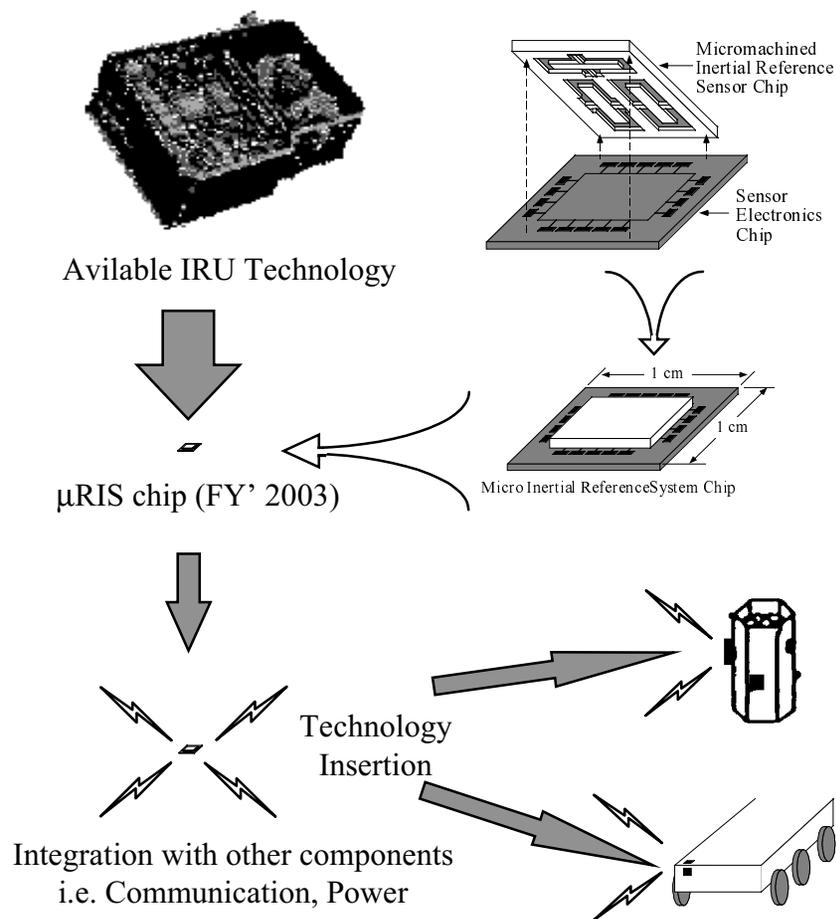
### On-Wafer Packaging



## 3-axes $\mu$ IRS prototype



## VISION



- Low mass ( $<5g$ )  
 *$>>1,000 X$  reduction*
- low volume ( $1cm \times 1cm \times 0.2cm$ )  
 *$90,000X$  reduction*
- High performance
  - $\mu$ gyro goal: ( $<1deg/hr$  bias stability)
  - $\mu$ accelerometer goal: ( $<micro-g$ )
- Low power consumption ( $< 0.2 Watt$ )  
 *$100X$  reduction*
- Inexpensive ( $<< \$10K$ )  
 *$>>25X$  reduction*
- Long lifetime ( $>20 years$ )  
 *$>2 X$  increase*
- Reduced electronics ( $1 chip$ )  
 *$>10 X$  reduction*
- Short turn-on time
- Radiation hardened